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Evaluation of spontaneous and weedy flora of vineyards for ecosystem services provision using the indicator VIFLORES

Avaliação da flora espontânea e infestante das vinhas para a provisão de serviços dos ecossistemas com recurso ao indicador VIFLORES

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A B S T R A C T

Spontaneous flora of vineyards in the Mediterranean region has lately been receiving much attention, due to the increasing awareness of their benefits for agroecosystems, soils, and for provisioning multiple Ecosystem Services (ES). However, initiatives for valuing flora often clash with the potential losses by interference with vines, but in an extent difficult to evaluate. We developed the index VIFLORES – **VI**neyard **FLOR**a Value for **E**cosystem **S**ervices -, aiming to assess the value of spontaneous plant species for ES provision in vineyards. VIFLORES ranges from 0 (lowest value) to 1 (maximum), calculated by the average of the contribution of the co-occurring species to the three ES categories: Provisioning (e.g. medicinal use), Regulation and Maintenance (e.g. pollination), and Cultural Services (e.g. landscape aesthetics). To map and compare the floristic values of vineyards, we propose an integration of species abundance, phenology and VIFLORES. To test this approach, we carried out 192 floristic surveys in Spring 2021 for three vineyards located in the Alentejo winegrowing region (South of Portugal) with different production management systems, namely Conventional (CPS), Integrated in Optidose (IPS), and Organic (OPS). IPS and OPS inter rows were significantly more diverse than CPS and had a high VIFLORES value. OPS vineyard rows had significantly higher diversity and indicator values than CPS and IPS, which is likely related to soil management. While VIFLORES approach guides to fostering of multifunctional vineyards, it is still limited in incorporating the seasonality of weedy flora and needs validated thresholds for better decisions on soil management.

Keywords: weeds, biodiversity, production management systems, sustainability, vineyard soil management.

R E S U M O

A flora espontânea das vinhas na região mediterrânea tem sucitado grande interesse recentemente, devido à crescente consciencialização dos seus benefícios para os agroecossistemas, o solo e no fornecimento de Serviços dos Ecossistemas (SE). No entanto, é comum estas iniciativas de valorização da flora colidirem com as perdas por interferência com as videiras. Neste trabalho, desenvolveu-se o indicador VIFLORES- Valor da Flora das Vinhas para Serviços dos Ecossistemas-, com o objetivo de avaliar a importância da flora das vinhas. O VIFLORES varia de 0 a 1 e é calculado pela média da contribuição das espécies para três categorias de SE: Provisão (ex. uso medicinal), Regulação e Manutenção (ex. polinização) e Serviços Culturais (ex. estética da paisagem). Para mapear e comparar os valores florísticos das vinhas, propomos uma integração da densidade das espécies, da fenologia e do VIFLORES. Para testar esta abordagem, realizámos 192 levantamentos florísticos na primavera de 2021 em três vinhas da região vinícola do Alentejo, sul de Portugal, com diferentes modos de produção: Convencional (CPS), Integrado em Optidose (IPS) e Biológico (BPS). As entrelinhas das vinhas IPS e BPS foram significativamente mais diversas que as CPS e apresentaram um maior VIFLORES. As linhas BPS apresentaram valores de diversidade e indicadores significativamente mais elevados que as CPS e IPS, o que poderá estar relacionado com a gestão do solo. Embora a abordagem VIFLORES oriente para a promoção de vinhas multifuncionais, ainda é limitada na incorporação da sazonalidade da flora espontânea e necessita de validação para uma melhor decisão na gestão do solo.

Palavras-chave: infestantes, biodiversidade, modo de produção, sustentabilidade, gestão do solo na vinha.

INTRODUCTION

For centuries, viticulture in the Mediterranean Basin was a friendly-biodiversity practice and vineyards were part of a heterogeneous and multifunctional landscape mosaic of various crops, including low-input grasslands and orchards. However, the increasing valuation of the wine sector and the availability of herbicides and improved machinery turn the typical Mediterranean vineyards in highly-labored lands to accomplish bare soil under vines and in the inter-rows (Paiola *et al*., 2020). This radical simplification of the ecosystem avoids the competition of the spontaneous flora for resources, their possible allelopathic effects and their contribution to the provision of pest habitats. In this perspective, these adventitious species of vineyards are considered weedy flora, as their occurrence and density are detrimental and cause economic losses. However, the reduced floral biodiversity, obtained through continued use of herbicides and high tillage frequency, has negative consequences on the *terroir*, as it modifies the local flora composition towards resistant perennial weedy species, and conveys wildlife declines, including the auxiliary fauna (Altieri & Nicholls, 2002). Additionally, the soil experiences nutrient runoff and detrimental thermal and water regimes which impair the productivity and quality of the grapes. The benefits of the spontaneous flora to the *terroir* and the provision of Ecosystem services, i.e. goods and services for human well-being and society, were not taken into account in these monotypic landscapes (Döring *et al*., 2022). Nevertheless, the last decades have been promising in finding balance in soil management and the coexistence of vines with other plants, supporting fauna and microbiota, and increasing awareness of their benefits for agroecosystems. The use of no-tillage production management systems has gained ecological, economic and social dimensions, as agri-environmental schemes are central strategic axes of the recent reform of the Common Agriculture Policy (CAP 2023). One of the CAP 2023-27 key objectives is to "contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes", which in practice refers to halting and reversing biodiversity loss in agricultural landscapes (EU, 2019).

In this scope, there are several methods to assess the differences in plant biodiversity with diverse production management systems, including taxonomic and diversity indices, and the indirect comparison of the effects of cover crops in relation to bare soil or to the traditional use of herbicide and mechanical weeding or increased diversity of other communities such as pollinators (e.g. Altieri & Nicholls, 2002; Monteiro & Lopes, 2007; Hall *et al*., 2020; Recasens *et al*., 2023). However, the use of indicators for the intrinsic value of spontaneous (or weedy) flora is still understudied, as well as the best ways to manage them (but see Garcia *et al*., 2018).

This study presents a framework using a new indicator of the value of flora for ES, (VIFLORES - **VI**neyard **FLOR**a Value for **E**cosystem **S**ervices), the phenological stage and abundance to evaluate the value of spontaneous flora of vineyards for ecosystem services provision.

MATERIALS AND METHODS

Study area, and sampling

To test VIFLORES approach and compare the value of vineyards for non-marketed services, we used three vineyards in Alentejo, South of Portugal. Case studies were vineyards with different production management systems selected in Alentejo wine region: Conventional, CPS (38°31′50.68″N; 7°53′52.33″W, Monte da Serralheira, 7 ha), Optidose integrated production, IPS (38°33′26.03″N; 7°51′40.67″W, Monte de Pinheiros, 10.5 ha), and Organic production, OPS (38°32′56.08″N; 7°51′19.88″W, Monte de Pinheiros, 4.5 ha). The vineyards were close to each other, thus having a similar Mediterranean climate with 600 mm of average annual rainfall and 16.5ºC of average annual temperature. Grapevines of the red variety 'Trincadeira' were spaced 2.5 m between rows and 1.0(1.2) m within rows, trained on a vertical shoot positioning system and spur-pruned on a Royat Cordon system. CPS vineyard was characterised by tillage and chemical application in rows and mowing in inter-rows. IPS had herbicide-sprayed rows, frequent mowing in rows and inter-rows (and occasional tillage). OPS used inter-row seeding every 3-4 years and resourced to mowing in rows and inter-rows. For more details consult Pires (2022).

Sampling

Fieldwork was carried out in April 2021 in sixty-four plots of 3x2 m^2 per production management system. Weed soil cover percentage was estimated visually for each species. Data on the species' phenological stage was also collected using a simple scale of five categories (1 - seedling; 2 - plants in rosette or tillering; 3 – mature plants; 4 – flowering; 5 – fructification). It was common to observe different phenological stages of individuals of the same species, and this was also noted (e.g. 4/5).

Index development, calculation and analysis

The more frequent and abundant species were evaluated for their contribution to three categories of Ecosystem Services (ES) and 13 subcategories: 1) Provision (n=5 subcategories), 2) Regulation and Maintenance (n= 5) and 3) Cultural Services (n=3) (Table 1). This information is converted in the index **VI**neyard **FLOR**a Value for **E**cosystem **S**ervices, a numerical value calculated for each species, ranging from 0 (null contribution) to 1 (maximum), according to the following formula:

$$VIFLORES_i = \frac{(ES\ Provision\ i)/5+(ES\ Regulation\ i)/5+(ES\ Cultural\ i)/3}{3};$$

where *i* is a plant species

We used a bubble graph, where dot size expresses the VIFLORES value of each spontaneous flora species. The x-axis presents the average cover of the species in all plots and the y-axis shows the dominant phenological stage(s).

Data treatment

The specific richness (S =number of species in each quadrat), Shannon-Wiener diversity index [$H'=\Sigma\ p_i \times \ln (p^i)$] , where p^i = proportion of individuals of species i, and Simpson's dominance [1-D; in which $D= \Sigma\ p_i^2$] were calculated for each management production system. One-way ANOVA was performed for each production system in rows and inter-rows, followed by multiple comparisons of the treatment effects with Tukey's HSD-test ($p < 0.05$). The U Mann–Whitney rank sum test was used when the assumptions of the ANOVA were not met. This analysis allowed us to relate the floristic diversity values of flora within the VIFLORES framework.

Table 1 - Components for the calculation of VIFLORES. Potential provision of ecosystem services (categories and subcategories) by a species of the spontaneous flora of vineyards according to the literature (databases, scientific articles) is noted as an x (Pires, 2022). Examples of four species of vineyard flora. // - toxic for animals. * - exotic species; social value relates to cultural traditions, including religious events, superstitions and symbolic uses

	PROVISIONING					REGULATION AND MAINTENANCE					CULTURAL			
Taxa	Livestock food	Seeds, harvestable parts of plants	Medicinal resources	Raw materials	Essences and industrial uses	Pollination	Pest regulation	Erosion control	Seed dispersion by birds	Seed dispersion by ants	Aesthetic value of the landscape	Social value	Scientific and educational value	**VIFLORES** (adimensional; 0-1)
Aster squamatus (Spreng.) Hieron.*			x				x	x						0,20
Avena barbata Link	x	x	x	x				x	x	x	x	x		0,69
Bromus madritensis L.								x	x	x				0,20
Echium plantagineum L.	//	x	x		x	x	x	x			x			0,51

RESULTS AND DISCUSSION

Forty-six taxa from 15 families were identified in rows and inter-rows of the studied vineyards. The most represented families were Asteraceae (12 taxa), Poaceae (10) and Fabaceae (7), in agreement with what was found by Hall *et al*. (2020) in a broad study of European vineyards. Vineyards in Optidose integrated production, IPS host more plant species (n=41), followed by Organic (OPS; n=37) and Conventional production, CPS (n=31). CPS inter-rows showed a significantly lower richness and diversity, and higher dominance in relation phenological status, allows us to visualize the services and disservices of the spontaneous vegetation of the vineyards (Figure 1). It can also give insights into management decisions. Figure 1 shows two examples: CPS rows are dominated by species with low VIFLORES, while OPS rows are dominated by *Trifolium fragiferum* L. and *Lolium rigidum* Gaudin, which can be related to mowing that promotes more diverse vegetation cover and the decline of annual broad-leaved species like Geraniaceae (e.g, *Erodium* sp.) (Monteiro & Lopes, 2007).

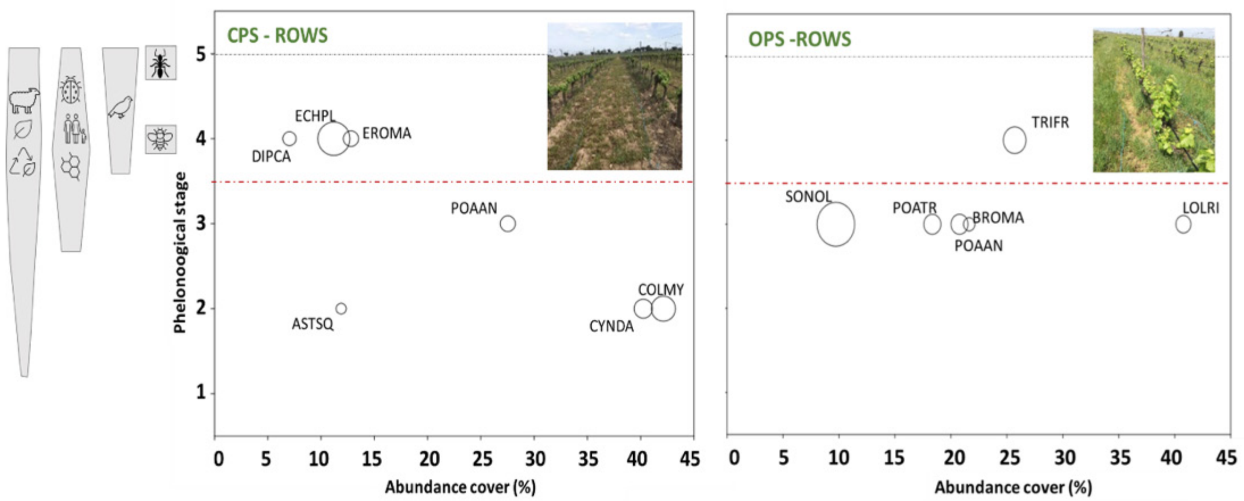

Figure 1 - Examples of two bubble graphs showing the VIFLORES for each species (circles), their abundance cover and phenological stage in CPS row and OPS – inter-row. Dotted line shows a threshold of phenology (adult plants to flowering plants) when most species can provide higher Ecosystem Services, ES. Grey bars present the relative (average) value of the ES for each subcategory concerning the phenological scale (e.g. pollination occurs in flowering plants; pest regulation by auxiliary fauna is more common in stages 3 to 5). See Table 1 to associate ES categories with icons. Photographs are from studied vineyards (April 2022). AVEBA – *Avena barbata* Link; ASTSQ – *Aster squamatus* (Spreng.) Hieron.; BROMA – *Bromus madritensis* L.; DIPCA – *Diplotaxis catholica* (L.) DC.; CYNDA – *Cynodon dactylon* (L.) Pers.; COLMY – *Coleostephus myconis* (L.) Rchb.f.; ECHPL – *Echium plantagineum* L.; EROMA –*Erodium malacoides* (L.) L'Hér.; POAAN – *Poa annua* L.; POATR – *Poa trivialis* L.; SONOL – *Sonchus oleraceus* L.; LOLRI – *Lolium rigidum* Gaudin; TRIFR - *Trifolium fragiferum* L.

to OPS and IPS. Dominance values of CPS were mainly due to the high abundance of *Coleostephus myconis* (L.) Rchb.f. and *Cynodon dactylon* (L.) Pers., the latter promoted by tillage that divides and disperses rhizomes and stolons of the species (Recassens *et al*., 2023). Nevertheless, the IPS rows had the lowest richness and diversity compared to the other production systems, likely due to high management intensity practices, including the use of herbicides (Guerra *et al*., 2022). The integration of the indicator VIFLORES, vegetation cover and

CONCLUSIONS

VIFLORES framework can be used as an indicator of the goods and benefits of spontaneous flora of vineyards and calls attention to the occurrence of competing species with low benefits for the vineyard and human well-being, usually referred to as weeds. However, this indicator needs improvements on several dimensions: i) ES subcategories weights (e.g. valuing more pest regulation than seed dispersal), ii) inclusion of vegetation dynamics throughout the year, iii) guidance on management decisions (e.g. decision on mowing or inter-row seeding).

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